GIOVANNI in the Arabian Sea

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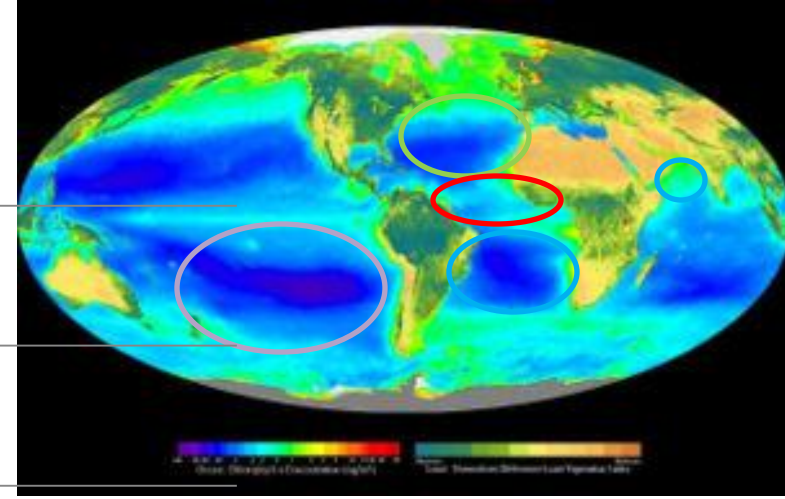
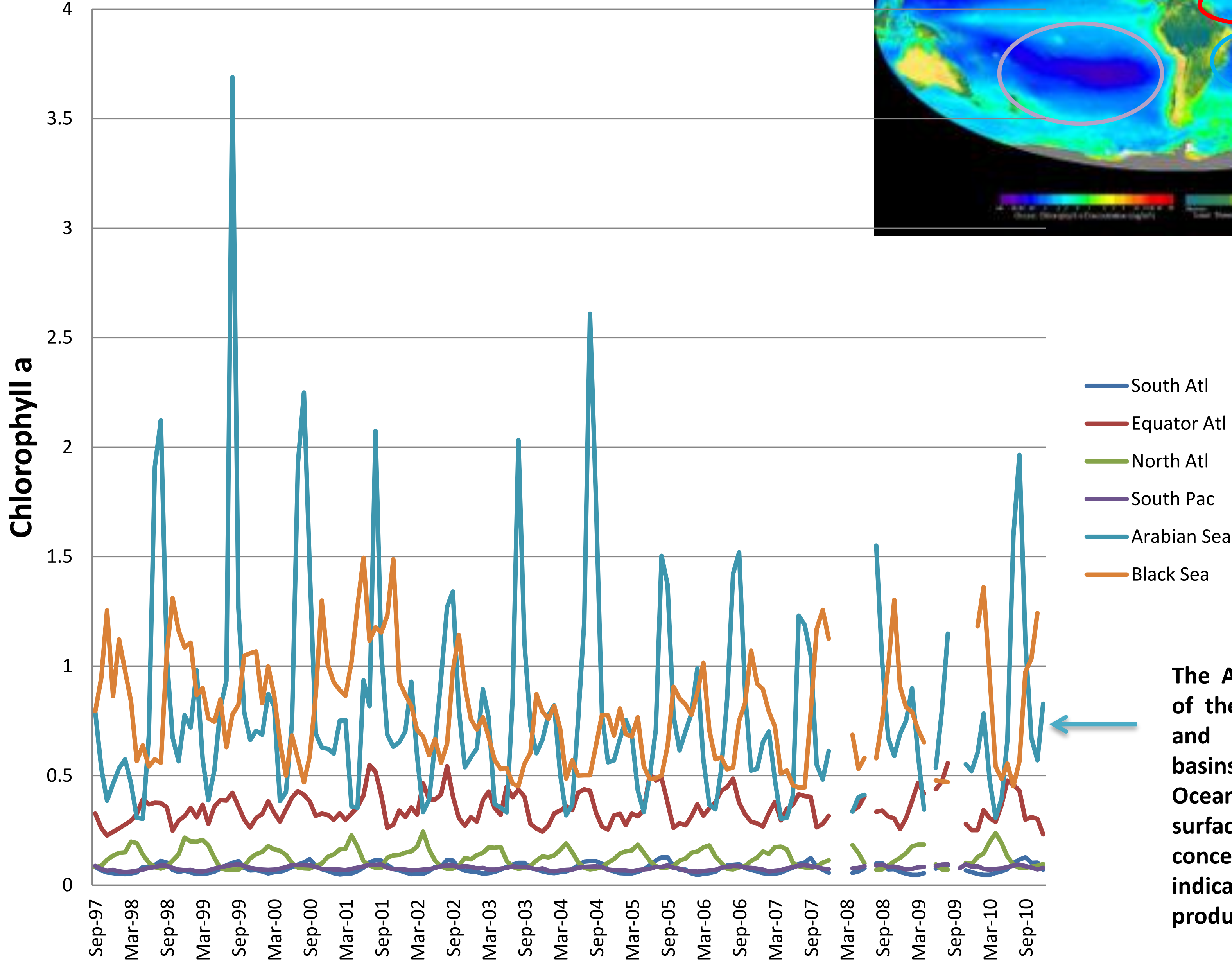
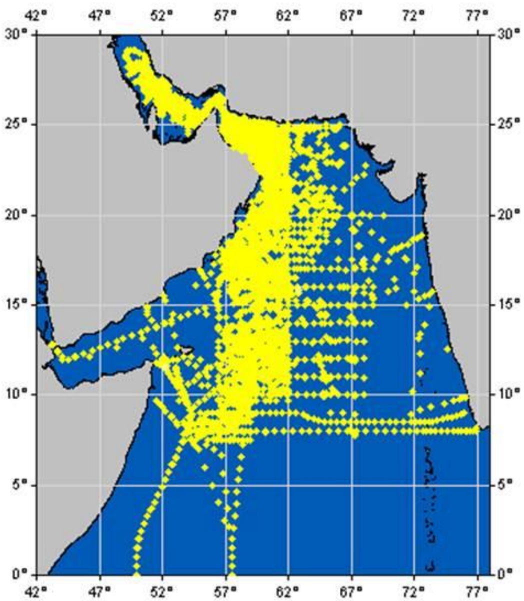
Data retrieved for the regions from the GIOVANNI data system





The Arabian Sea is one of the most productive and most variable basins of the World Ocean (as far as the surface chlorophyll is concerned as the indicator of productivity).



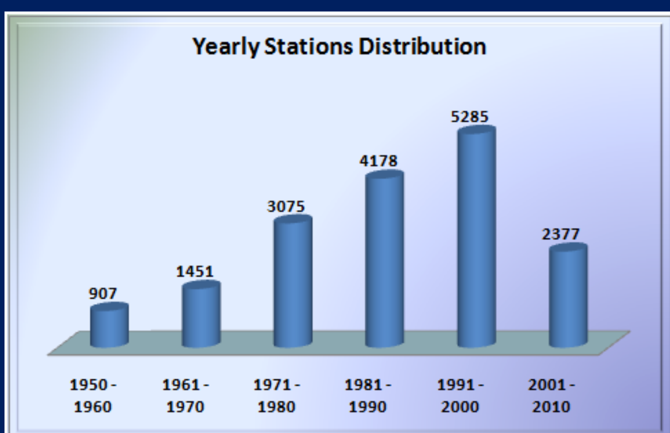
Historical data on oceanographic sampling assembled for the Sea of Oman region (1950-2010)

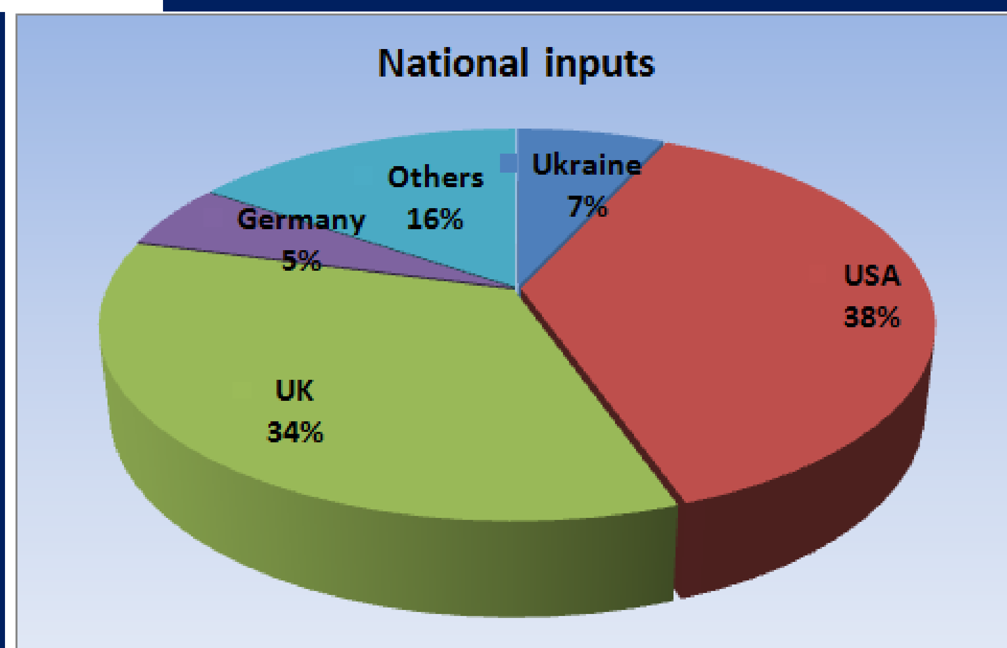
-oceanographic stations

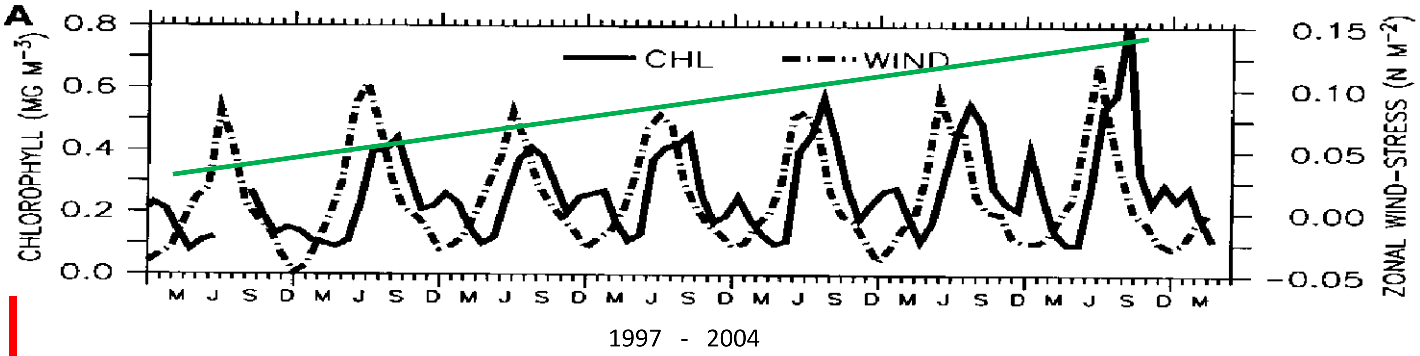
Objectives:

To understand seasonal, interannual, and mesoscale changes of epipelagic ecosystems of the western Arabian Sea.

In order to do that, a regional database incorporating the onboard ***oceanographic surveys*** and ***remotely sensed data*** on physical, chemical, and biological parameters were assembled.



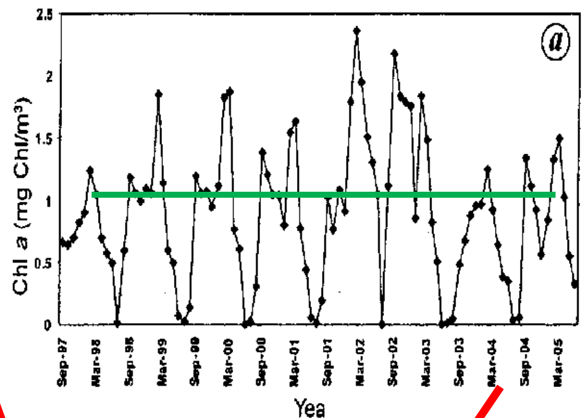


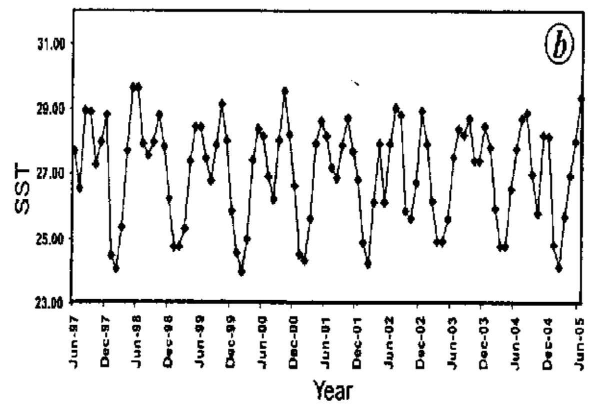


Western Arabian Sea

Goes et al. ,

Science, 2005

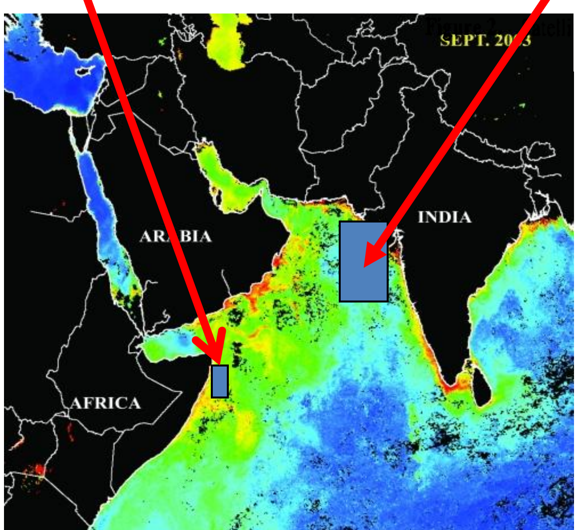




Eastern Arabian Sea

Prakash & Ramesh,

Current Science, 2007

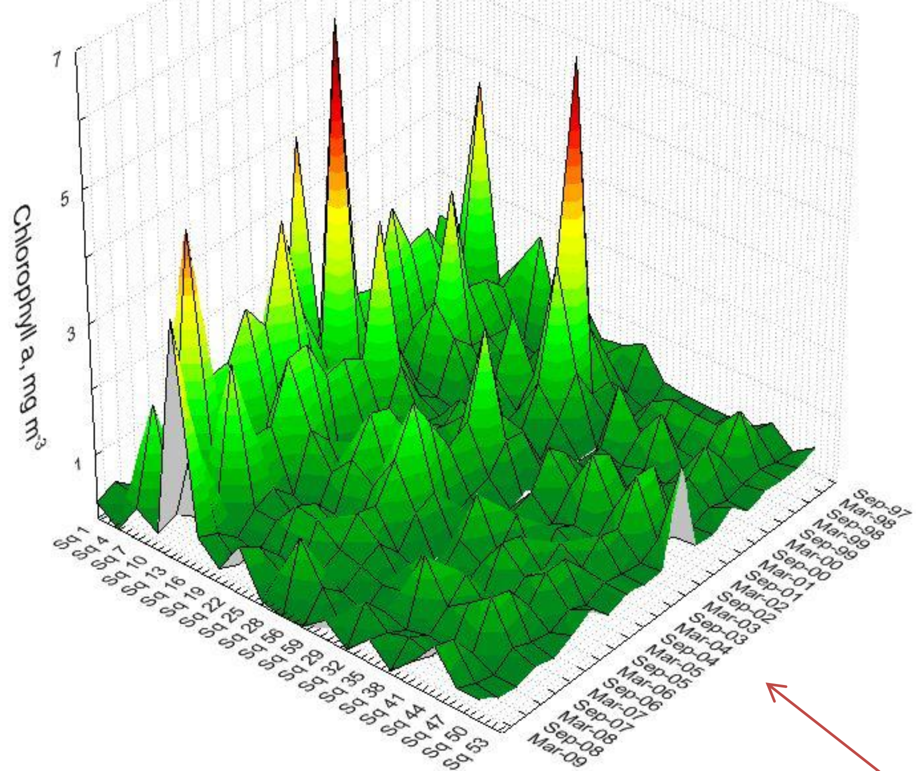


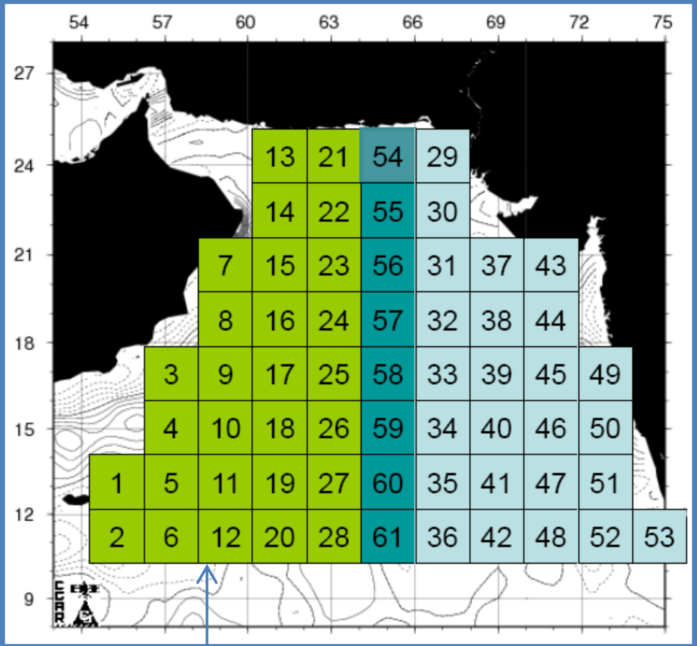
Previous findings

By correlating satellite-derived sea surface temperature against chlorophyll-a during the summer months (SW monsoon), Goes et al (2005) concluded that the increasing strength of sea surface winds was largely responsible for the increase in phytoplankton biomass in the western Arabian Sea during that period. The authors suggested that the increase in productivity might have far-reaching consequences for the biogeochemical balance of the Indian Ocean.

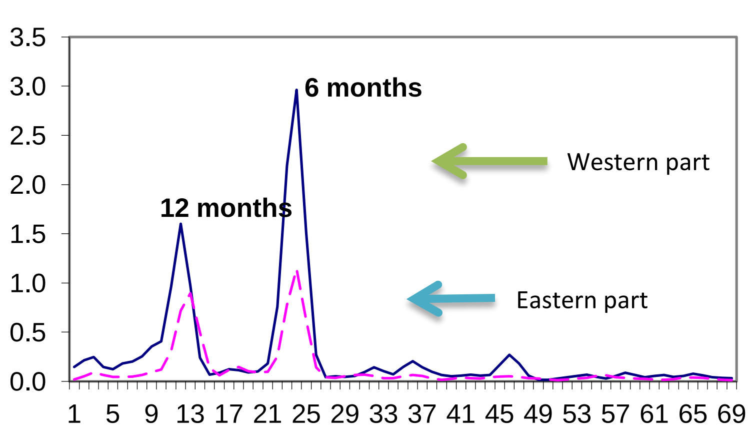
Prakash & Ramesh (2007) investigated the productivity in the eastern part of the Arabian Sea during an 8-year period (1997-2005). They divided the eastern Arabian Sea into two large zones and found that remotely sensed chlorophyll-a concentrations had not changed significantly over these 8 years, so the positive trend in chlorophyll reported for the western Arabian Sea was not observed in the eastern part.

Data retrieved for the regions from the GIOVANNI data system



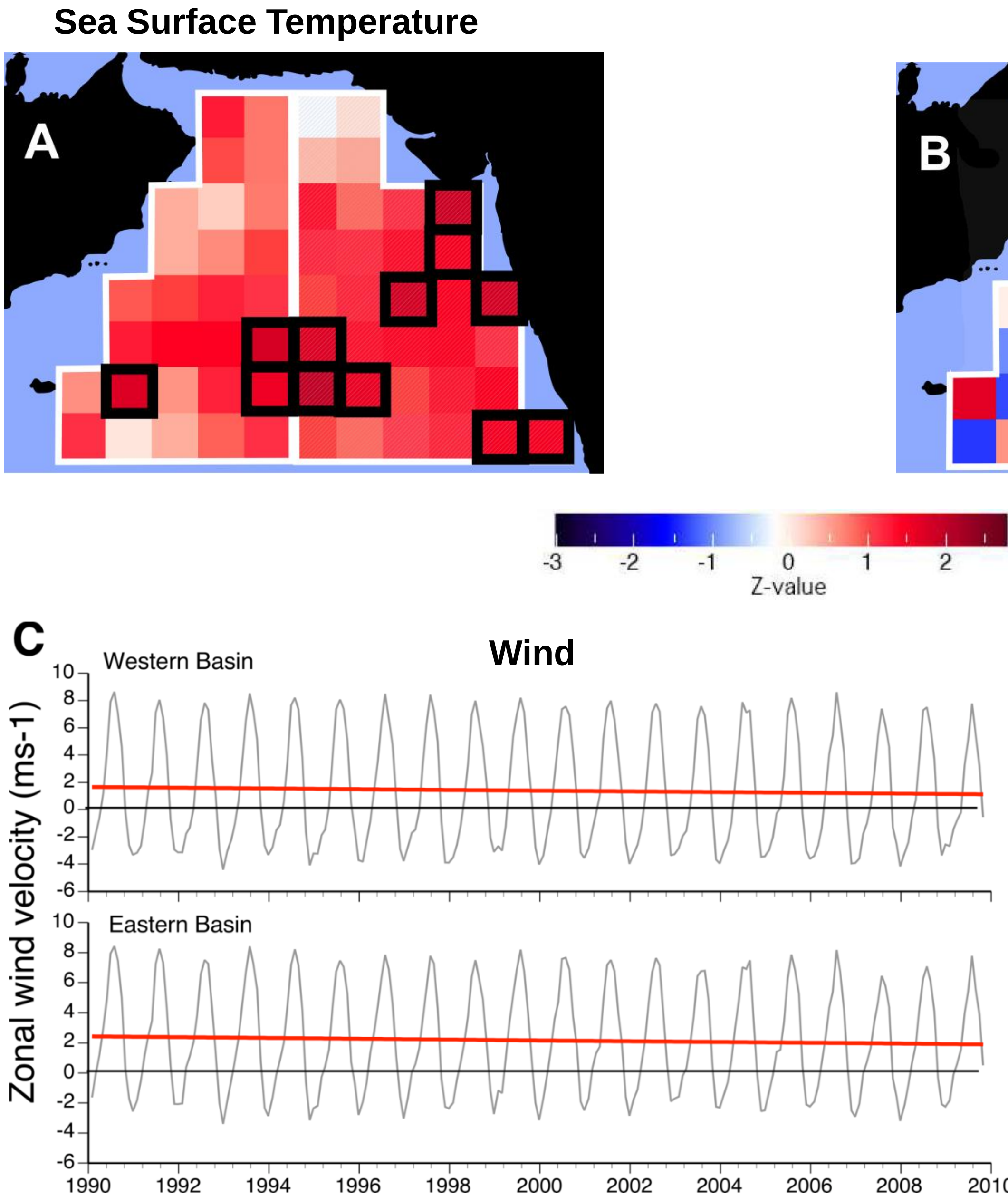


Mean power spectra of chlorophyll variance



Our approach in data analysis: 2º regions covering the Arabian Sea;

Monthly time series of chlorophyll-*a* and power spectra for each region (1997-2009).

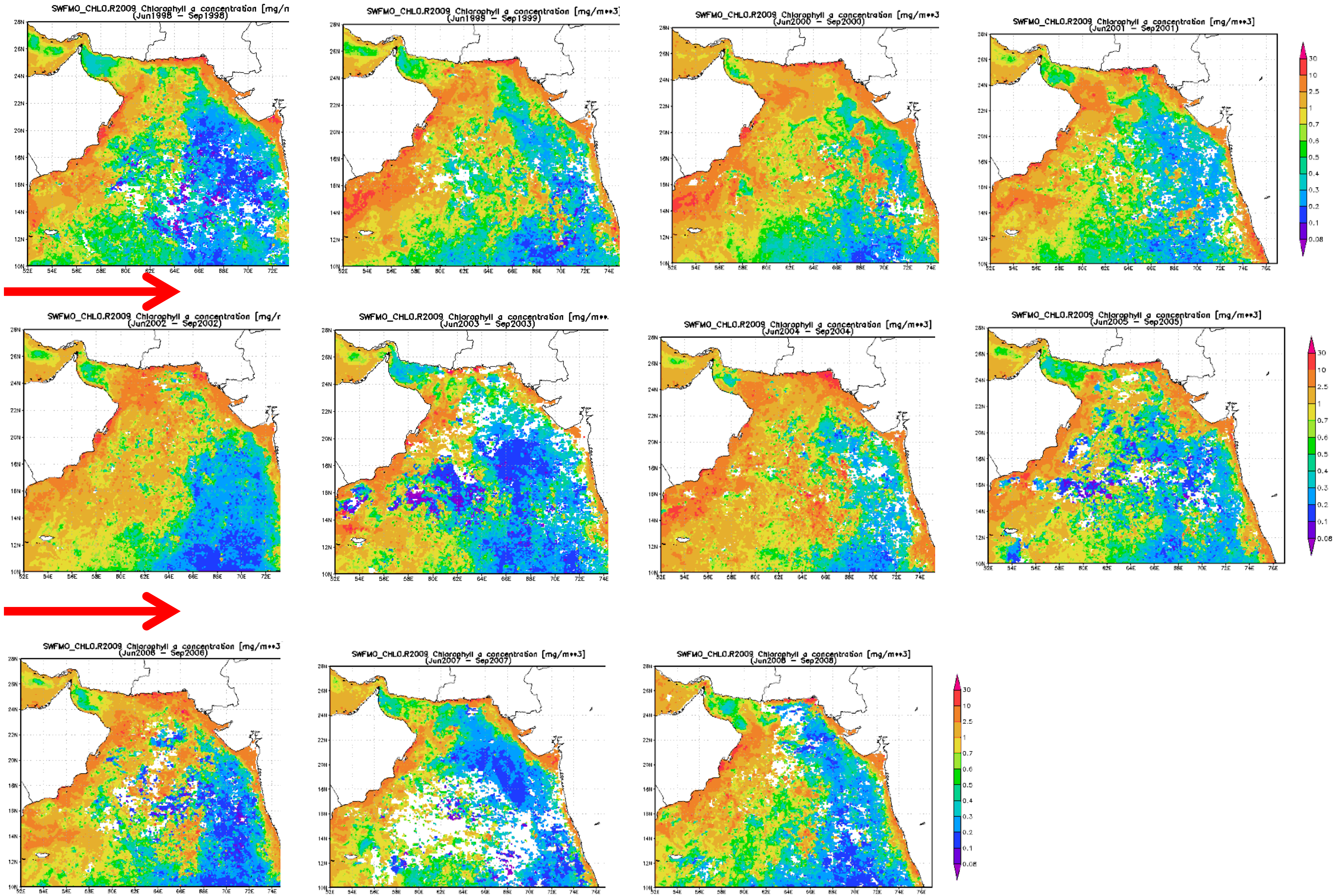


(**A**): Color coded temperature trends in 61 2ºsquares in the Arabian Sea between 1997-2009.
Color corresponds to the Z-significance value of the Mann-Kendall test. **Positive trends are red**, **negative trends are blue**. Significant values (p<0.05) are framed by a **thick black border.**

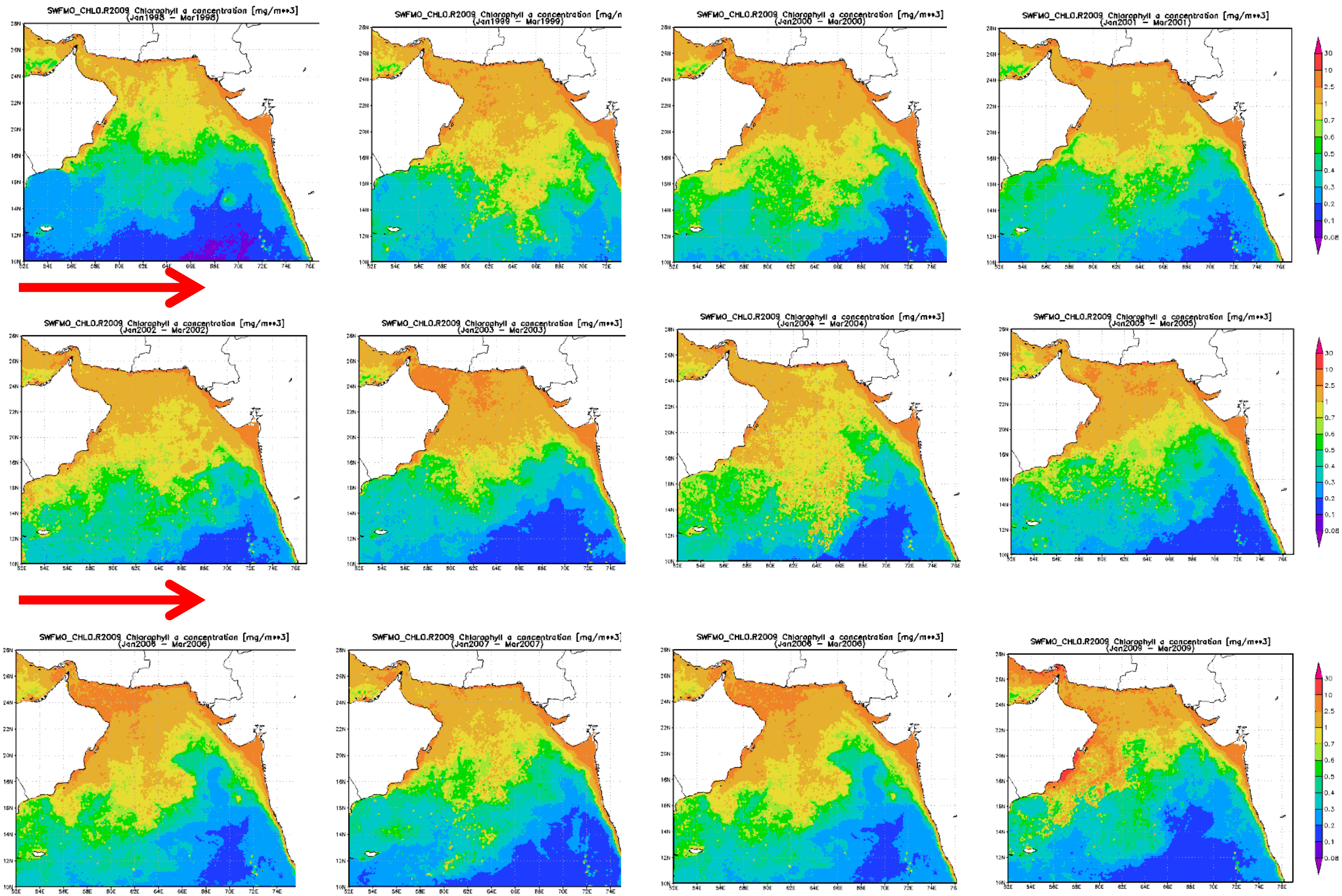
(**B**): Color coded chlorophyll-*a* trends in 61 2º Squares in the Arabian Sea 1997-2010.

(**C**): Zonal Wind Velocity over the Western and Eastern basins of the Arabian Sea. Both linear trends shown in red are significant (Mann-Kendall test, p<0.001).

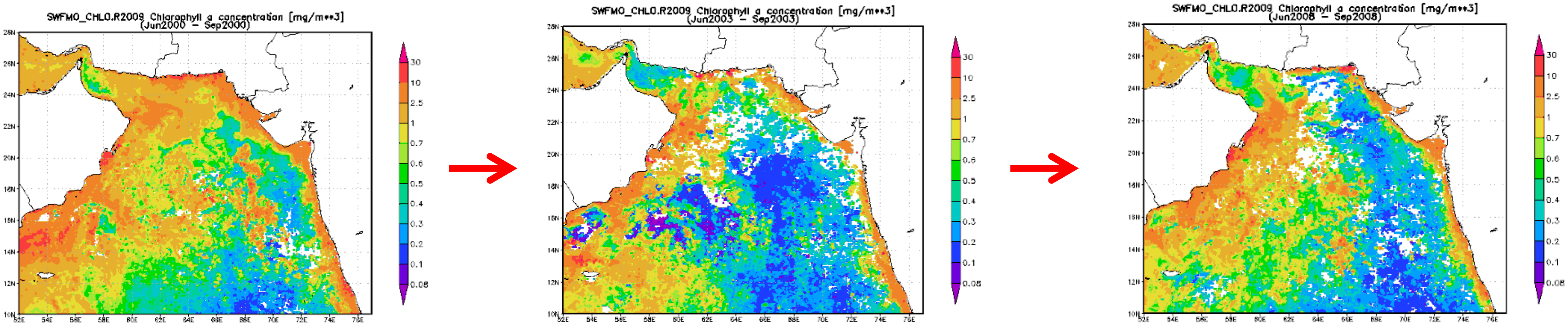
Piontkovski & Claereboudt, 2012



Interannual variability (1998-2008): Chlorophyll-*a.* Summer monsoon.

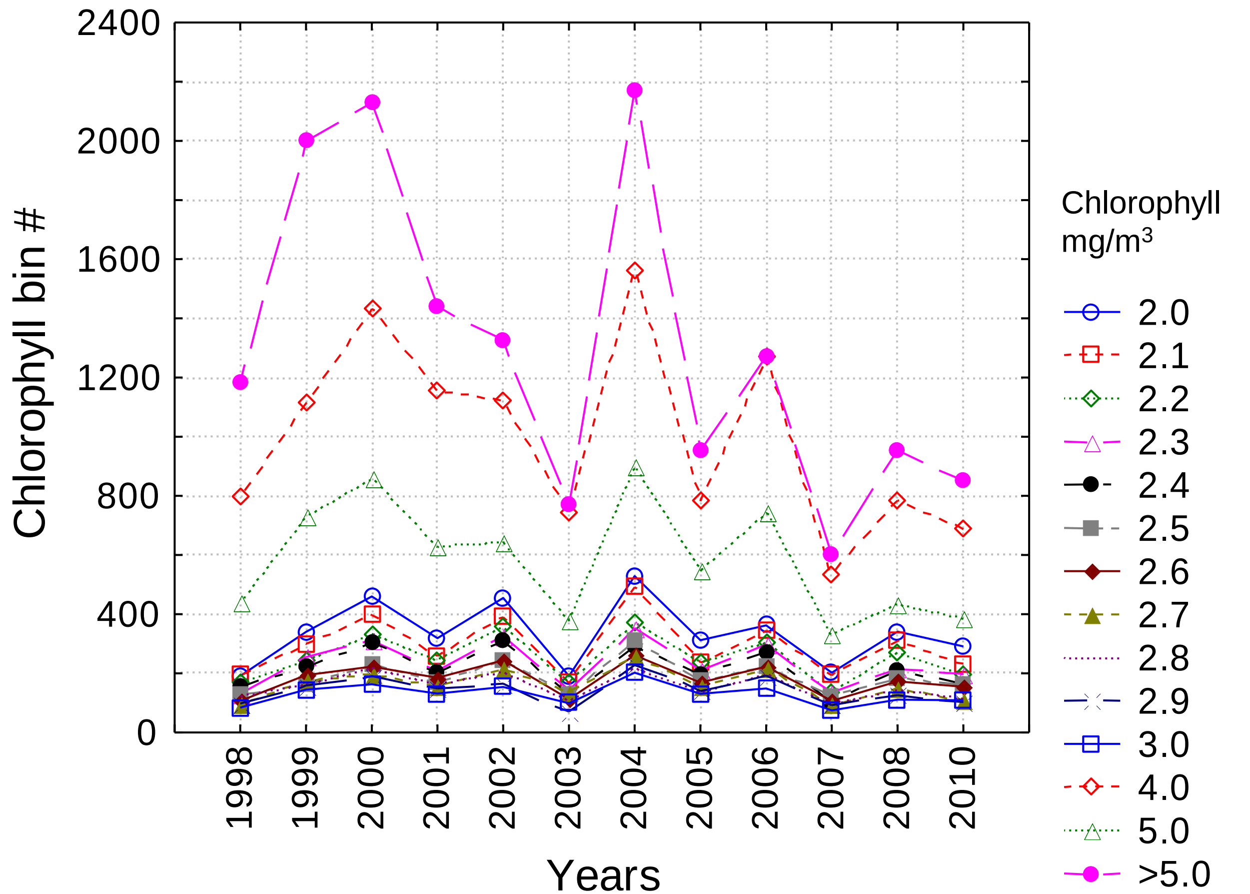


Interannual variability (1998-2008): Chlorophyll-*a.* Winter monsoon.



Interannual changes of the size of areas covered by chlorophyll concentrations (Summer monsoon).

The concentration values exerted fluctuations with dominant periods of 6 month and 1 year- both mediated by the reverse of monsoonal winds. However, the productive regions have decreased spatially. This is evident in interannual changes of the zones of maximal concentrations which have diminished spatially.



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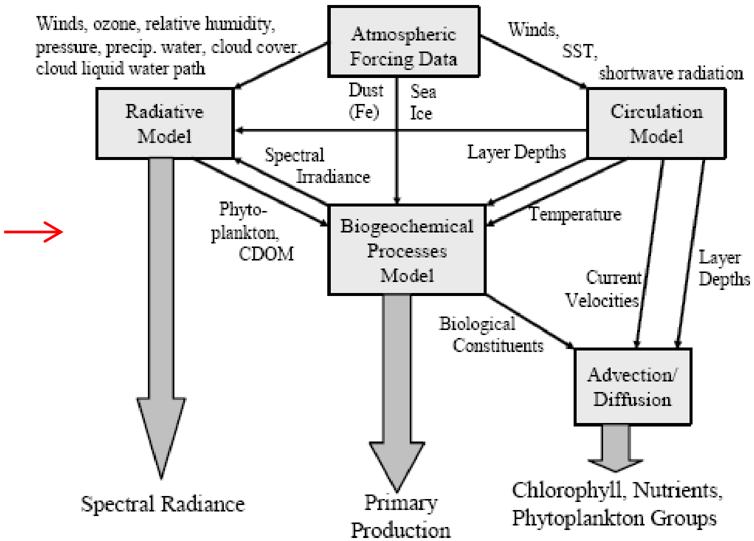
Modeling physical-biological coupling in the region

Data on concentration of nitrates and mixed layer depth were retrieved from the **NASA Ocean Biogeochemical Mode**l, which is a coupled three-dimensional model incorporating general circulation, biogeochemical, radiative components and assimilating monthly global products.

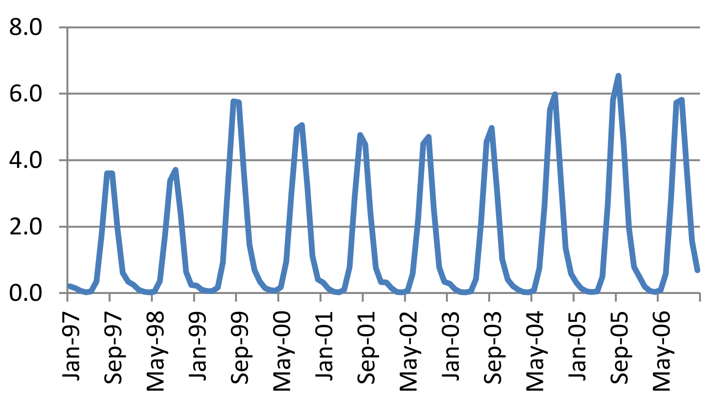
This 14 vertical layers model is driven by wind stress, shortwave radiation and sea surface temperature.

NASA Ocean Biogeochemical Model

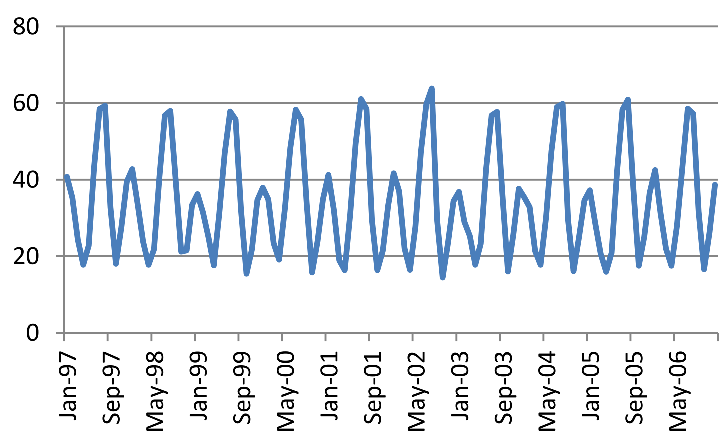


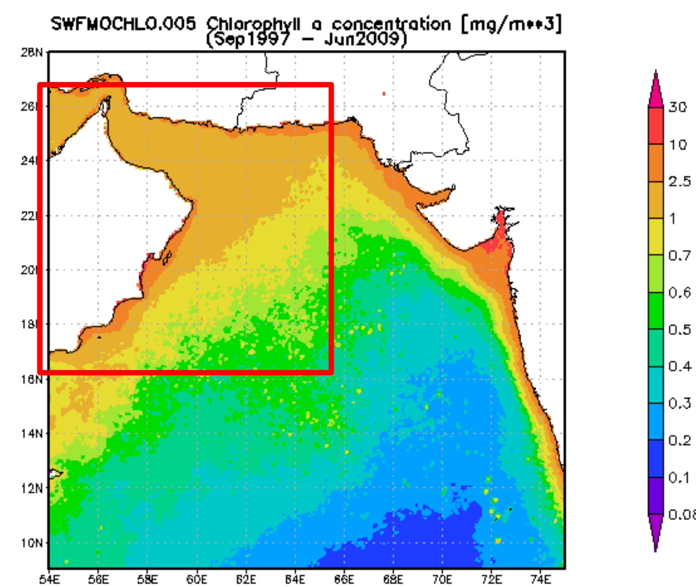
(Gregg, 2005)

Nitrates, micromol



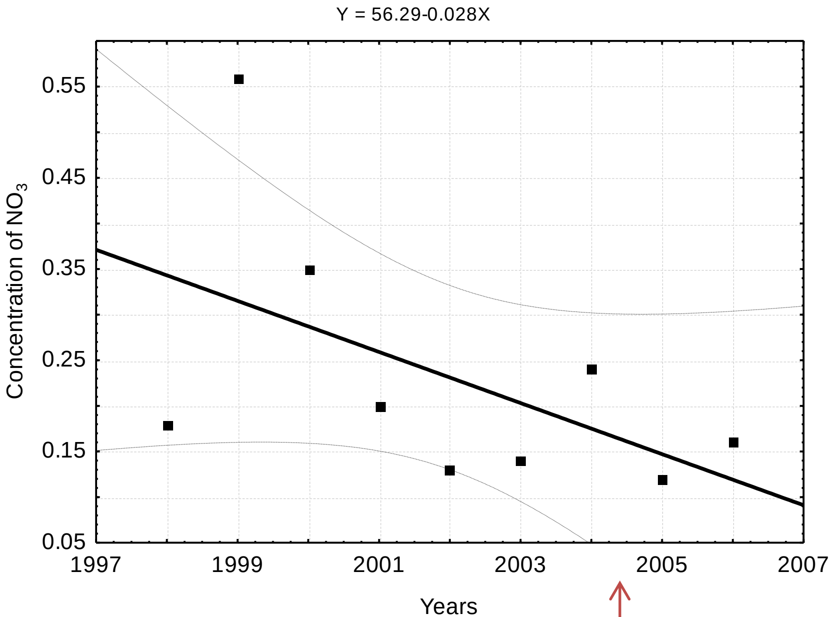
Mixed layer depth, m

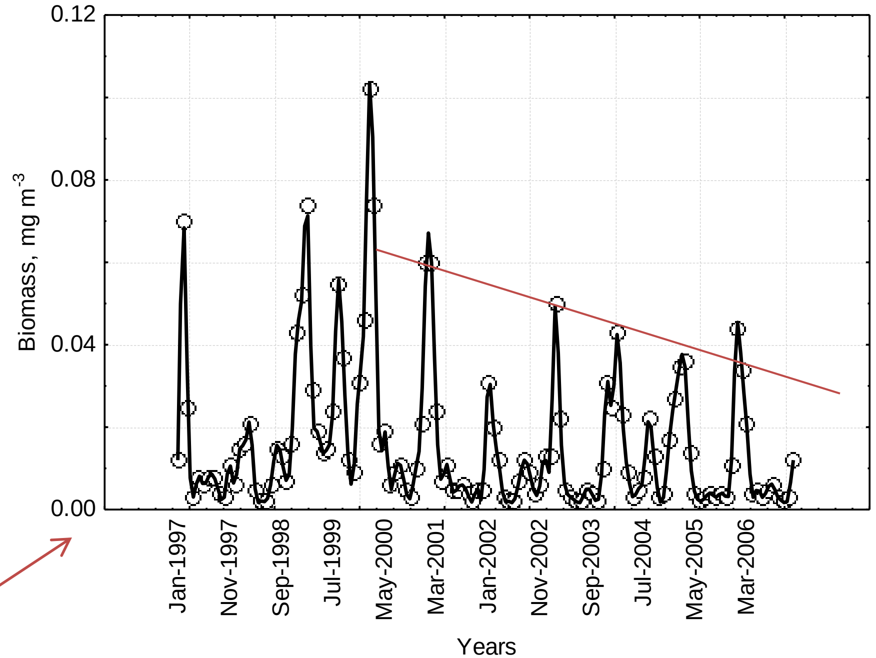




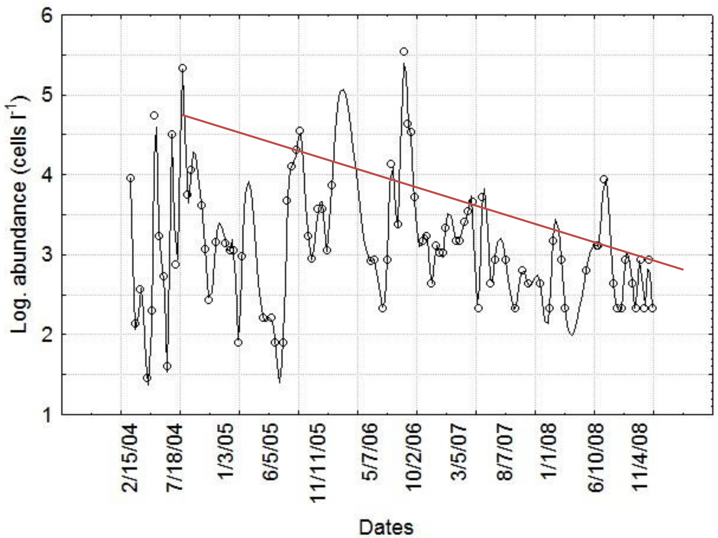
Data retrieved from the GIOVANNI data system

Modeling: the NASA Ocean Biogeochemical Model. The modeled and observed trends.



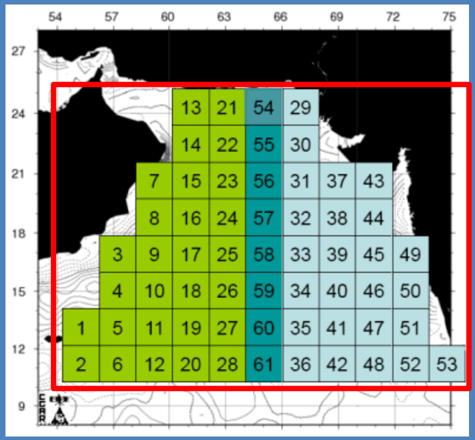


Interannual changes of nitrates and diatom biomass in the Sea of Oman.



Results of sample processing: monthly changes of diatom abundance in the Bandar Hyran Bay (1m depth).

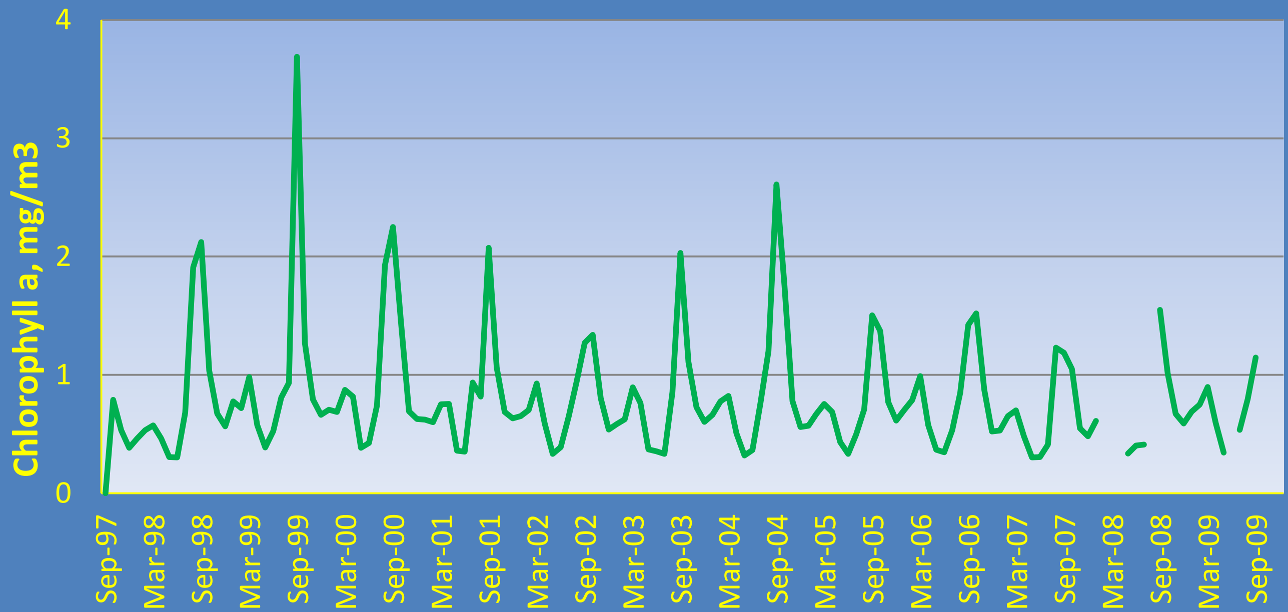
Piontkovski et al, 2012



Overall, the Arabian Sea upper layer is a balanced system exhibiting physical-biological oscillations with typical period of 12 and 6 months (reflecting the seasonality of monsoonal winds), with no rising trends of chlorophyll *a*, on the time scale of the past 12 years (1997-2009).

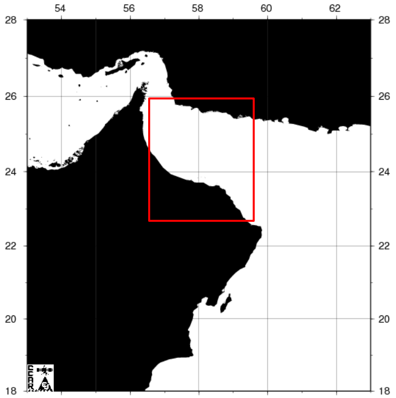
The basin scale maps of chlorophyll-*a* distribution did not show the enlargement of productive zones over the past 12 years. The Arabian Sea is getting warmer and it is not getting more productive.

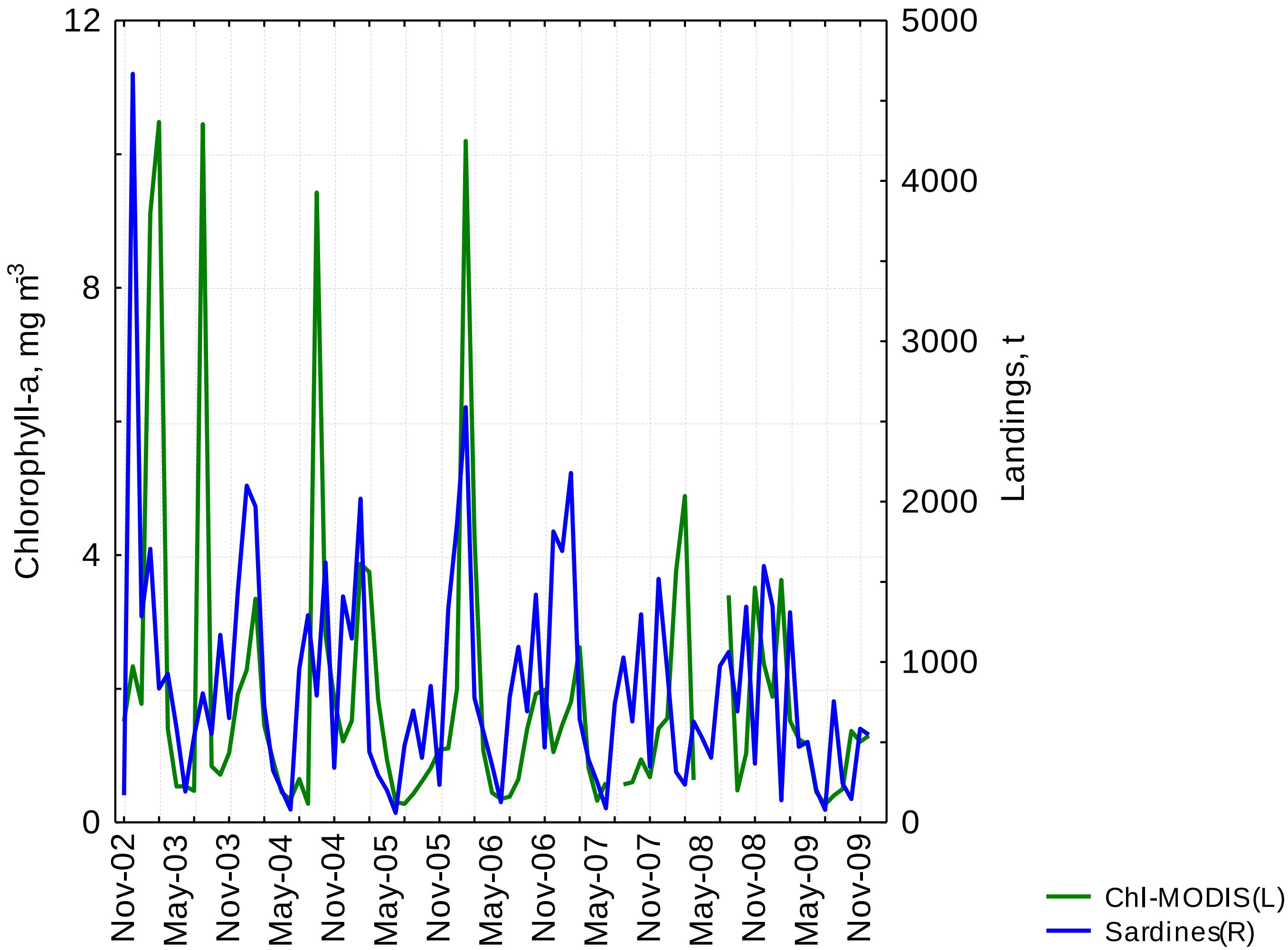
The two-way dispersion analysis showed that monthly variability of the chlorophyll concentration exceeded its basin scale spatial variability (the normalized variance in monthly time series exceed the normalized variance of the spatial pattern featuring a certain month - for instance, the basin scale spatial distribution in January, or in July).
This allowed us to construct the basin scale monthly time series.



Basin-averaged interannual changes of chlorophyll -*a*

Chlorophyll-a and fishery: Monthly time series of chlorophyll and sardine landings



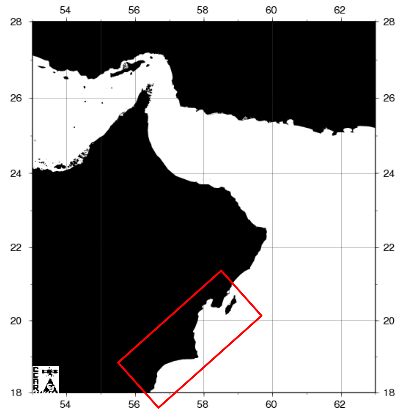


Sardines comprise about 50% to the total landings in the region.

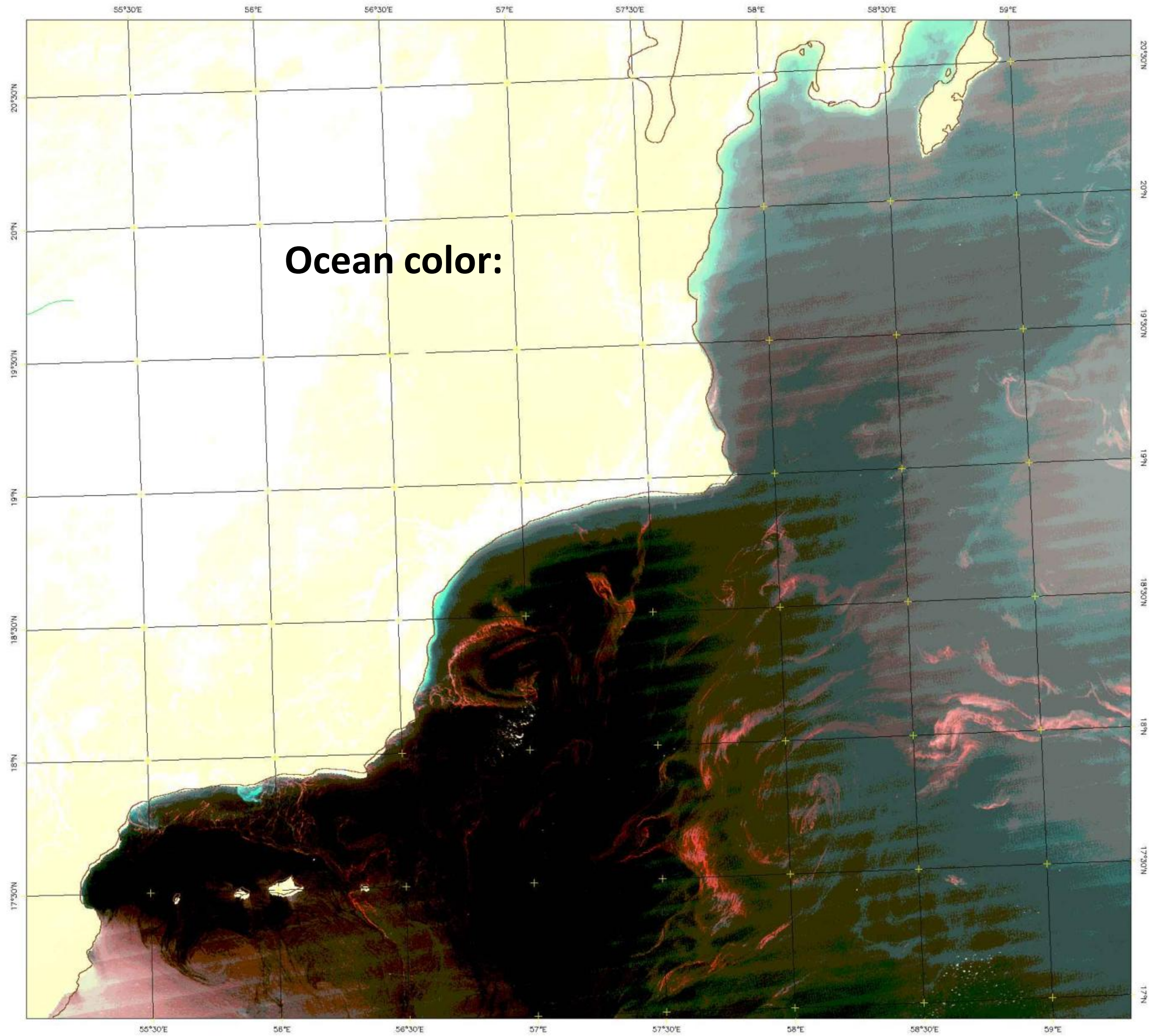
Being filter feeders, sardines are tightly related to spatial-temporal changes of phytoplankton concentration.

Chlorophyll data for the region were retrieved from the GIOVANNI data system.

Piontkovski & Al-Jufaili, in press



Mesoscale variability



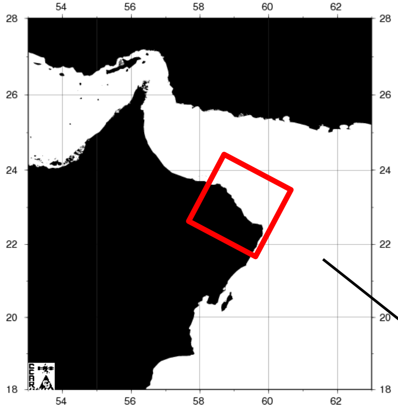
Ocean color:

Along with basin scale variability, we study the mesoscale physical-biological interactions in the western Arabian Sea, with a special reference to algal blooms and fish kill incidents.

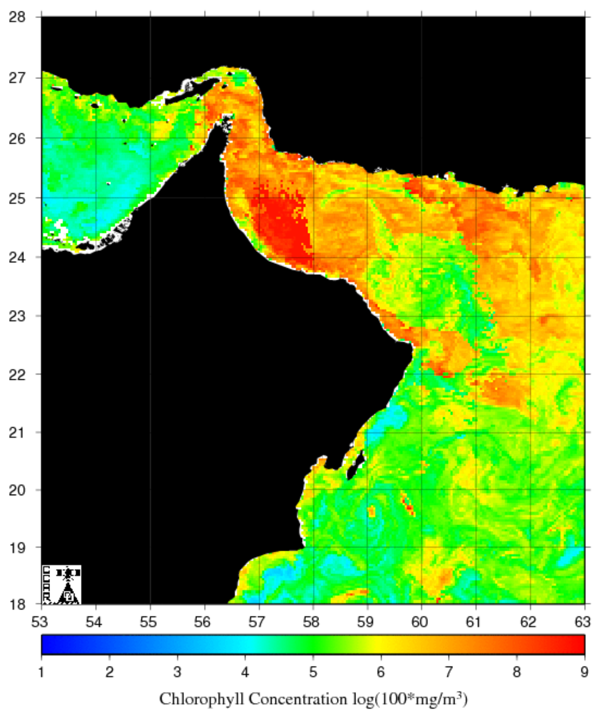
The high resolution images is a courtesy of the ROPME remote sensing group.

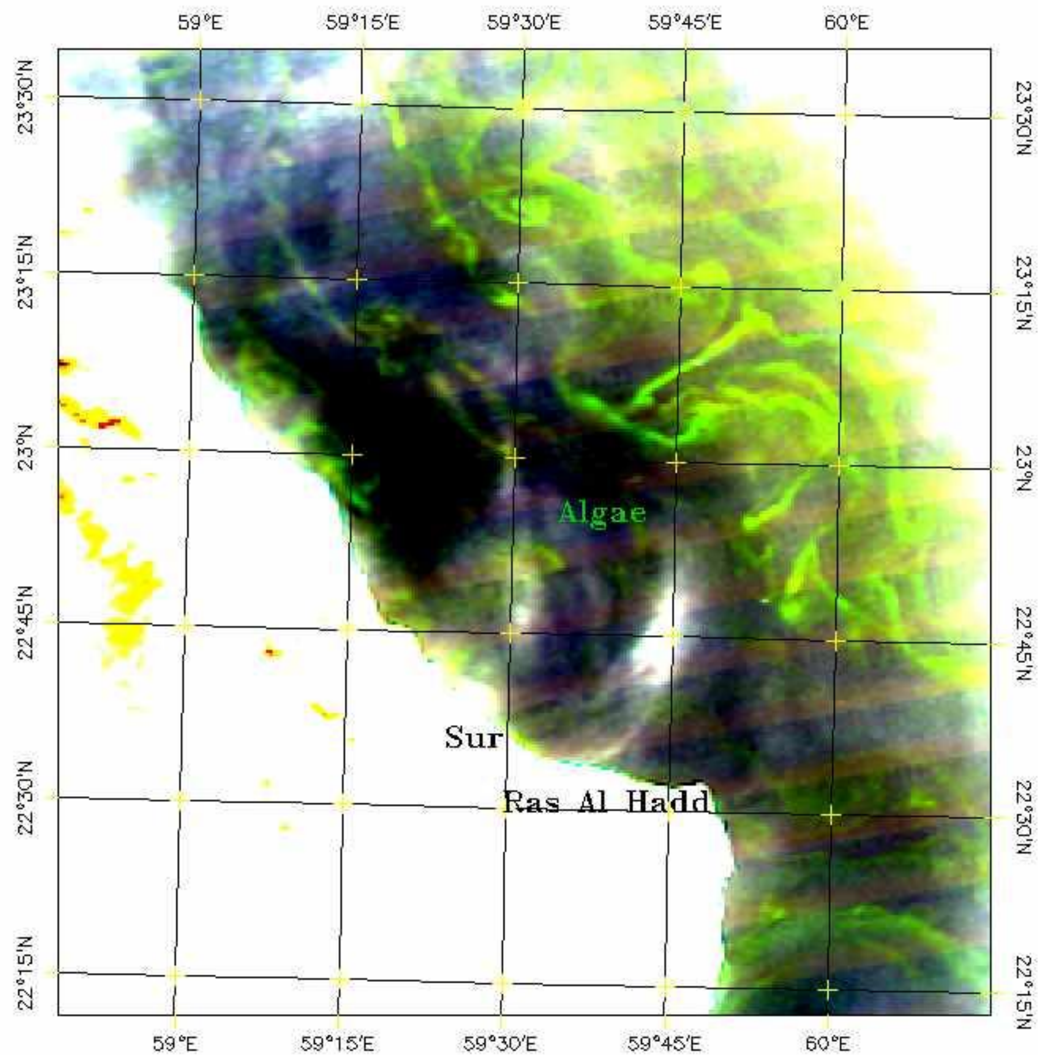
Mesoscale structure of a winter bloom (MODIS-Aqua)

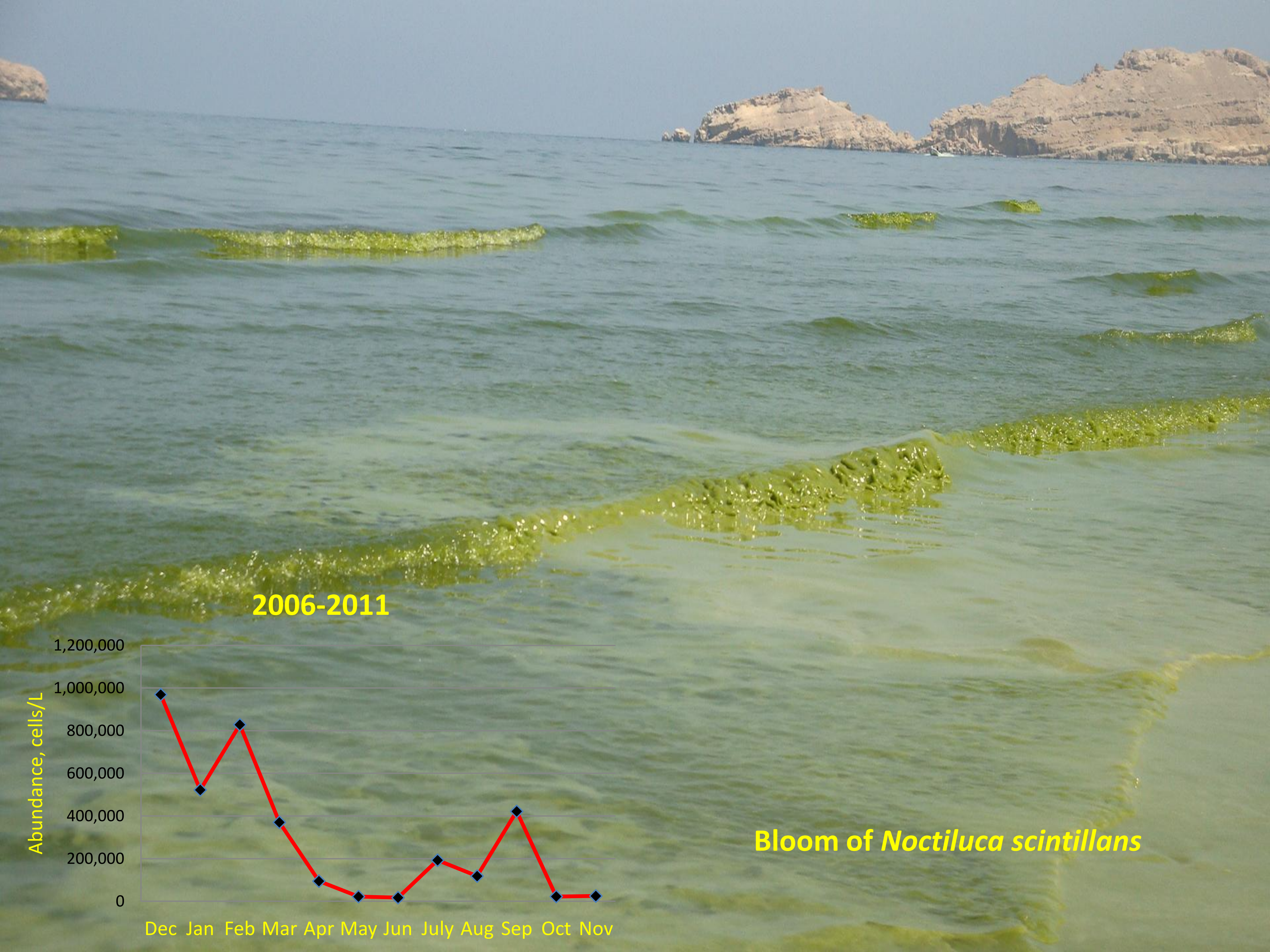
In the Sea of Oman, the Noctiluca blooms are the dominant ones.

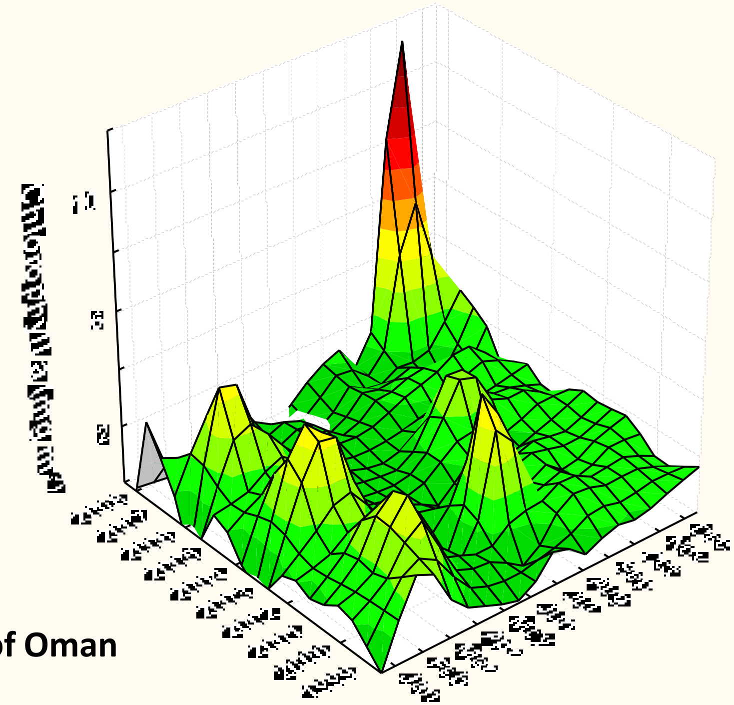


Chlorophyll Concentration - Mar 1 2008





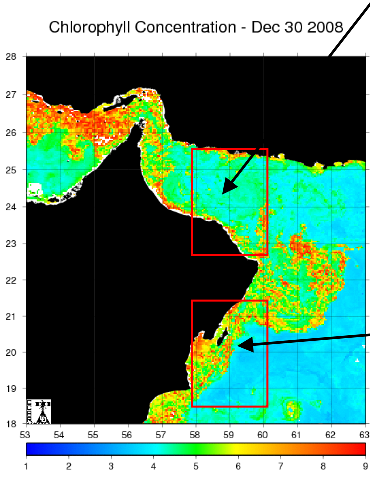

2006-2011
Abundance, cells/L
1,200,000
1,000,000
800,000
600,000
400,000
200,000
0
Dec Jan Feb Mar Apr May Jun July Aug Sep Oct Nov
Bloom of *Noctiluca scintillans*



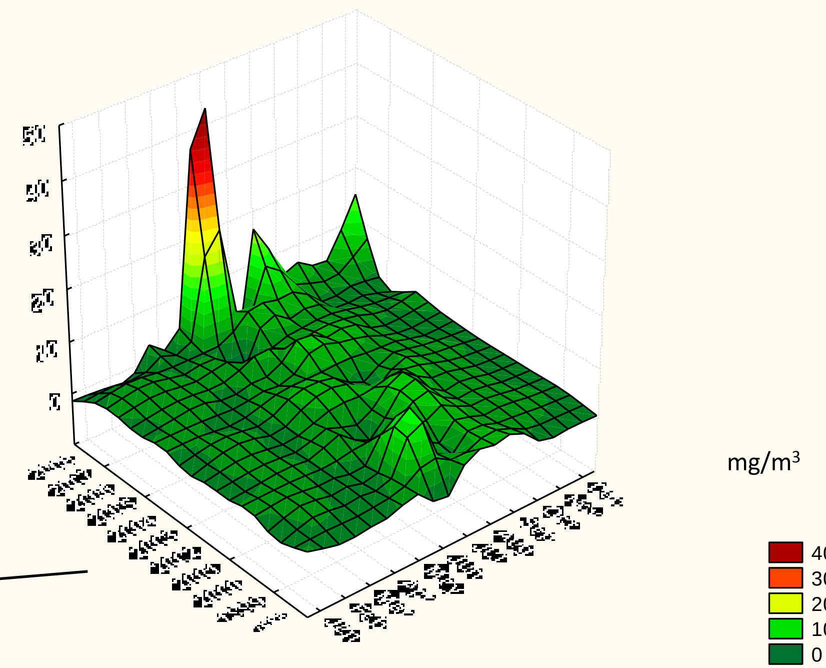
The Sea of Oman

Interannual changes of seasonal cycles

(SeaWIFS data)

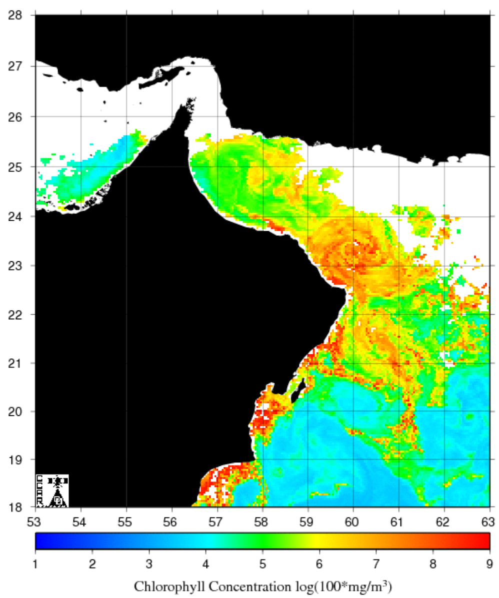


Data retrieved for the regions from the GIOVANNI data system

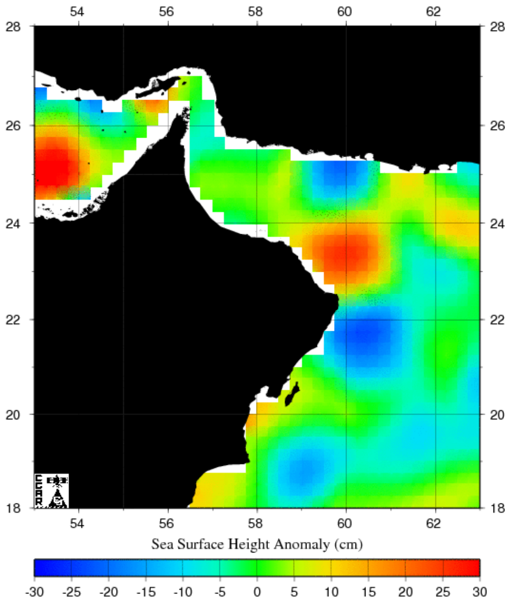


The western Arabian Sea

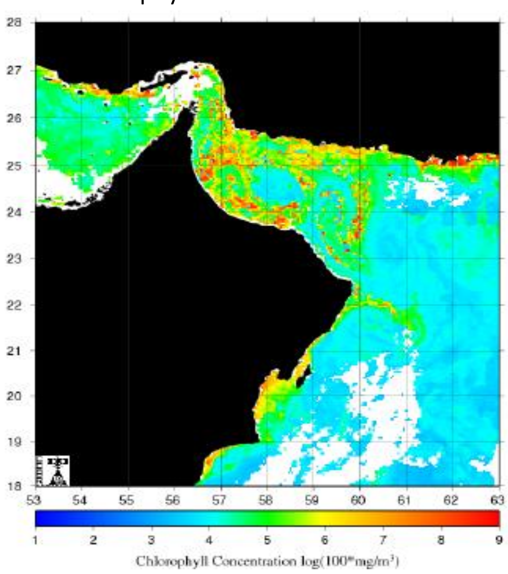
Chlorophyll Concentration - Feb 25 2009



Real-Time Mesoscale Altimetry - Feb 20, 2009



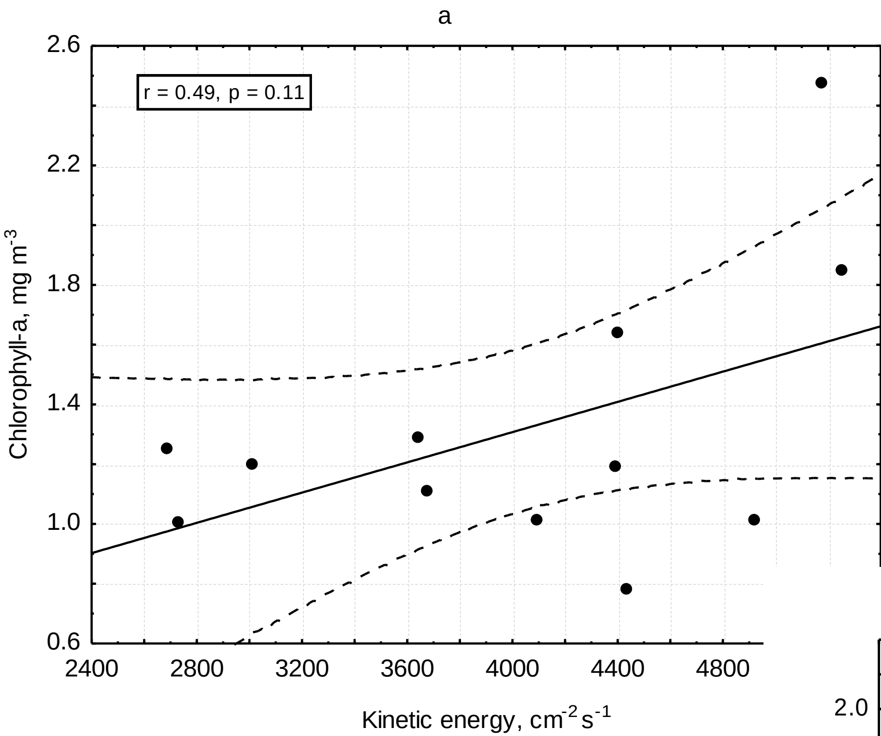
Chlorophyll Concentration - Nov 5 2008

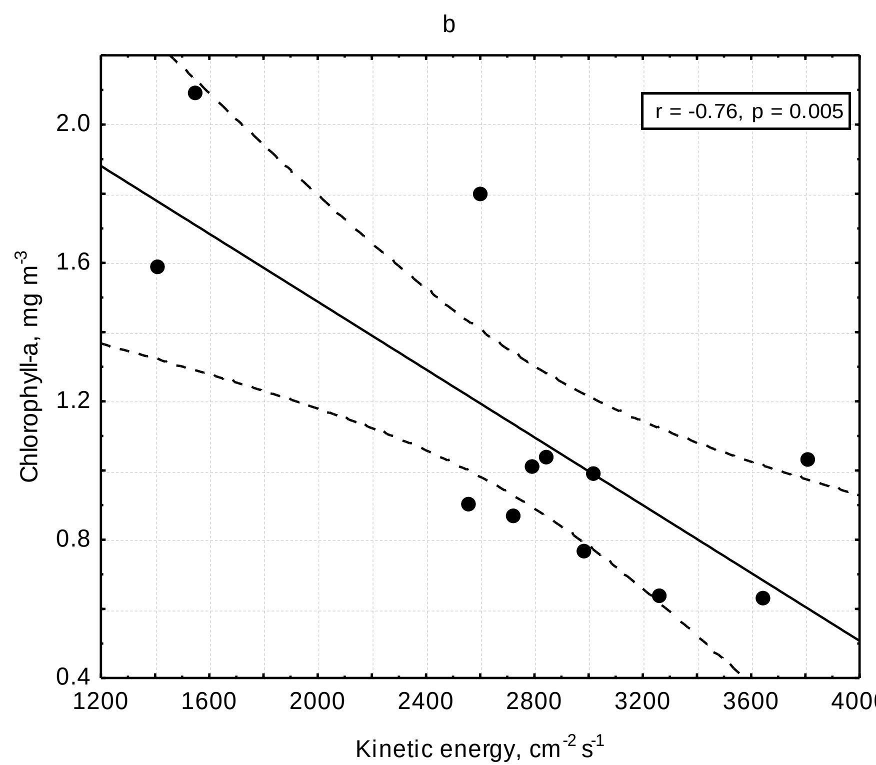


Mesoscale variability: Distribution of chlorophyll-*a* in the field of cyclonic and anticyclonic eddies.

MODIS satellite sensor. Maps were retrieved from the CCAR Global Near Real-Time SSH Anomaly/Ocean Color Data Viewer (http://argo.colorado.edu)

The western Arabian Sea is known for its vigorous field of mesoscale eddies. In years when cyclonic eddies dominate throughout the annual cycle, the chlorophyll-a concentration is positively related to the kinetic energy of eddies. For the other years, when the total annual balance of negative to positive sea surface heights was dominated by anticyclonic eddies, the correlation between kinetic energy and chlorophyll was negative.



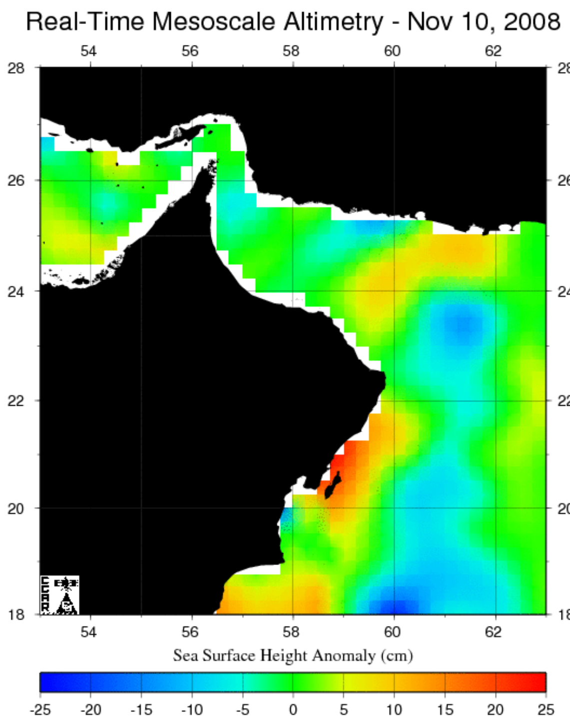


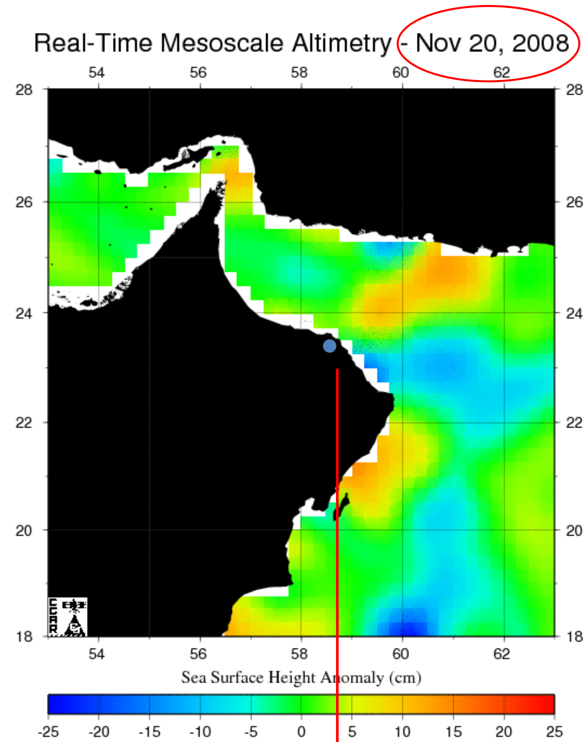
Types of relationship between chlorophyll -*a* and kinetic energy of eddies in the western Arabian Sea

a: year 2003, b: year 1998.

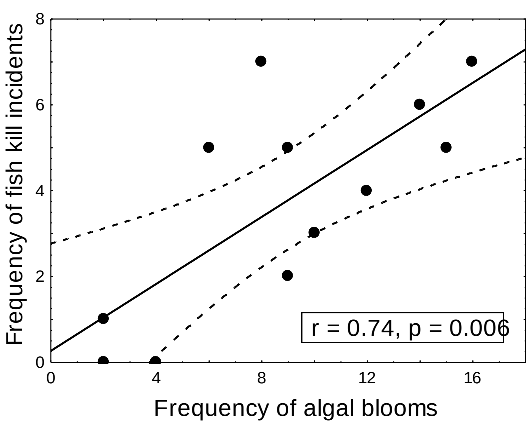
Piontkovski and Nezlin, in press

Mesoscale variability and fish kill incidents



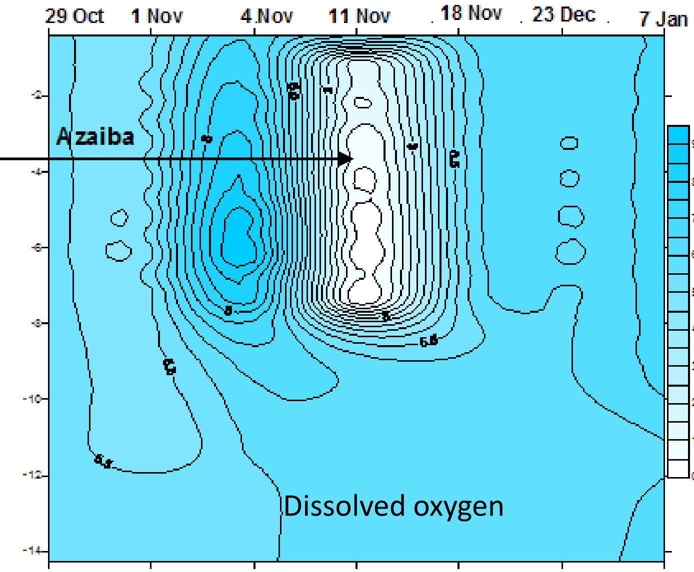


The relationship between the frequency of fish kills and algal blooms on a scale of the Omani coast.

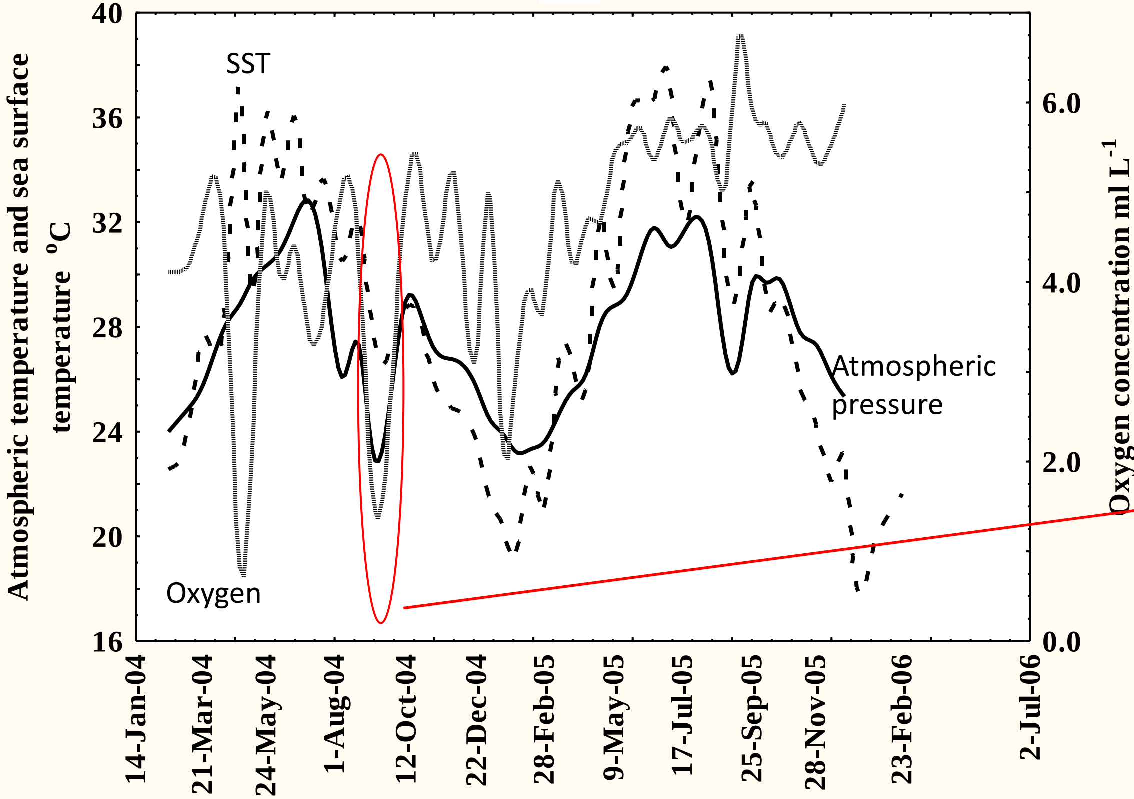


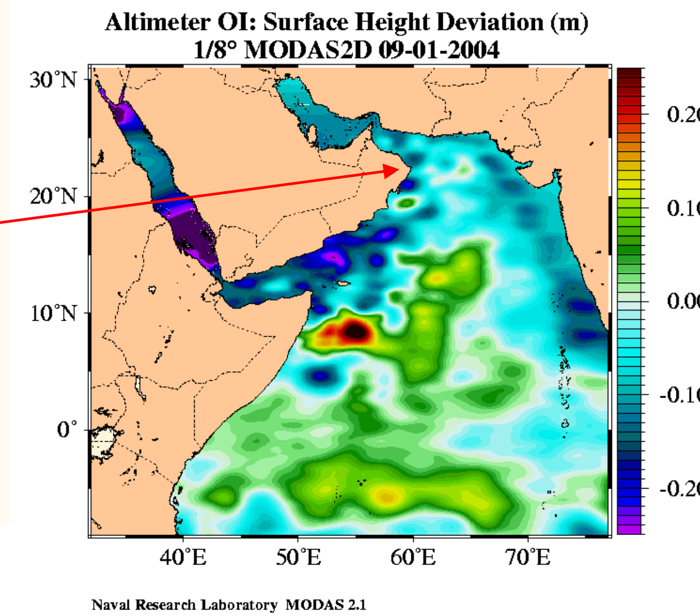
November 23, 2008: 70 tons of fish (Sea bream-*Sparus aurata)* were killed by oxygen depletion at Qurayiat culture farm (Muscat), *at 0.1ML/L dissolved oxygen concentration recoded.*

Oxygen depletion (time series of vertical profiles)



Sudden drops of the dissolved oxygen concentration observed in our coastal time series might be related to the mesoscale events like eddies, wind pulses, or filaments of currents.





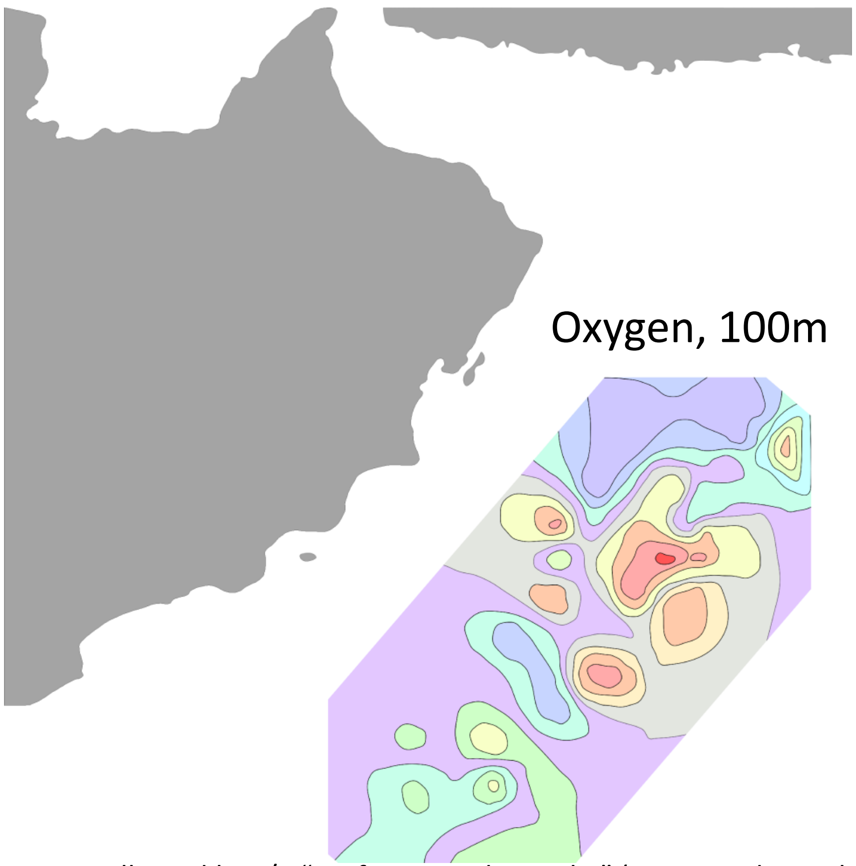
The eddy which reached the coastal zone (in red)

(Piontkovski et al, 2011)

In analyzing the Omani coastal region, 23 environmental variables were assembled in the form of time series. The Ridge Multiple Regression Analysis implied *the dissolved oxygen concentration* and *monthly frequency of algal blooms* as the two variables explaining 75% of the seasonal variation in fish kill incidents.

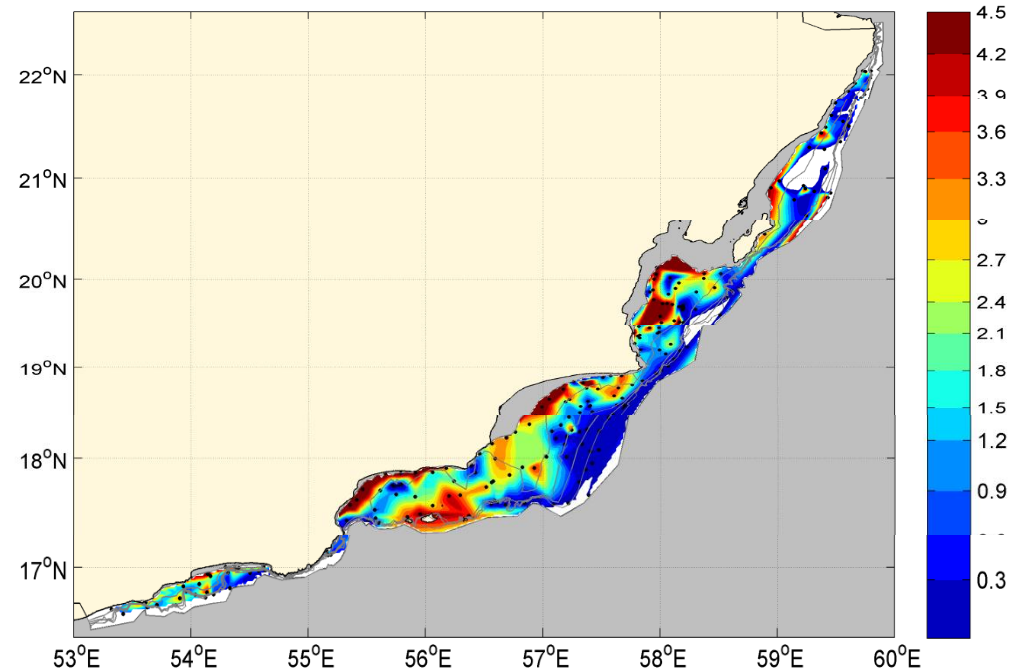
Mesoscale eddies generate patchy distributed zones of oxygen-poor waters. Being associated with the Rossby waves, they propagate westward (towards the Omani coast).

In the figure below, blue and green colors represent oxygen depleted waters; yellow and red colors indicate waters with high oxygen concentration.



Data collected by r/v “Professor Vodyanitsky” (Banse and Piontkovski, 2006).

CTD field survey (January-March, 2008, data from MSFC): the bottom dissolved oxygen (mg/l).



Piontkovski et al, in press

The GIOVANNI-related publications (2008-2012)

Book chapters

1.Piontkovski S.A. and A. Al-Azri. 2010. Influence of a tropical cyclone GONU on phytoplankton biomass (chlorophyll a) in the Arabian Sea. In: Charabi Yassine (Ed.). Indian Ocean Tropical Cyclones and Climate Change. Springer, pp. 339-348.

2.Al-Azri A.R., S.A.Piontkovski, K.Al-Hashmi, J.Goes, and H.Gomes. 2010. Recent outbreaks of Harmful algal blooms along the coast of Oman: possible response to climate change? In: Y.Charabi (Ed.). Indian Ocean Tropical Cyclones and Climate Change. Springer, pp. 349-358.

Peer-Reviewed Publications

3. Al-Azri A.R., S.A.Piontkovski, K.Al-Hashmi, H. Al-Gheilani, H. Al-Habsi , S. Al-Khusaibi, N.Al-Azri. 2012. The Occurrence of Harmful Algal Blooms (HABs) in Omani coastal waters. Aquatic Ecosystem Health and Management, 15 (S1): 56-63.

4.Piontkovski S.A., H. Al-Gheilani, B.Jupp, A.R.Al-Azri, and K.A.Al-Hashmi. 2012. Interannual changes in the Sea of Oman ecosystem. The Open Marine Biology Journal, 6: 38-52.

5.Piontkovski S.A. and M.R.Claereboudt. 2012. Interannual changes of the Arabian Sea productivity. Mar.Biol.Res., 8: 189-194.

6.Piontkovski S.A., N.Nezlin, A.R.Al-Azri, and K.Al-Hashmi. 2011. Mesoscale eddies and interannual trends of physical-biological coupling in the Sea of Oman. Intern. Journ. Remote Sensing, 33, 17: 5341-5346.

7.Piontkovski S.A., A.R.Al-Azri, and K.A.Al-Hashmi. 2011. Seasonal and interannual variability of chlorophyll a in the Gulf of Oman compared to the open Arabian Sea regions. Intern. Journ. Remote Sensing, 33, 22: 7703-7715.

8.Al-Hashmi K., A. M. Claereboudt, A. R. Al-Azri, and S. A. Piontkovski. 2010. Seasonal changes of chlorophyll "a" and environmental characteristics in the Sea of Oman. The Open Marine Biology Journal, 4: 107-114.

9.Al-Azri A.R., S.A.Piontkovski, K.A.Al-Hashmi, J. I. Goes, and H. R. Gomes. 2009. Chlorophyll *a* as a measure of seasonal coupling between phytoplankton and the monsoon periods in the Gulf of Oman. Aquatic Ecology, 44, 2: 449 – 461.

***Website*:** www.omansea.org

Acknowledgments

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Drs. Hamed Al-Gheilani, Adnan Al-Azri, Khalid Al-Hashmi, Michel Claereboudt, Saud Al-Jufaili, Peter Petrov, and Nik Nezlin –all contributed to this presentation.

This research was supported by grants from the Sultan Qaboos University, Ministry of Fisheries Wealth Fund, and The Research Council (#ORG/EBR/09/004).

The GIOVANNI software was extremely helpful in data assembly and data analysis.


Thank you
(Shukran)